STATE OF VERMONT

PUBLIC SERVICE BOARD

Joint Petition of Green Mountain Power Corporation, Vermont Electric Cooperative, Inc. and Vermont Electric Power Company, Inc. for a Certificate of Public Good pursuant to 30 V.S.A. § 248, to construct up to a 63 MW wind electric generation facility and associated facilities on Lowell Mountain in Lowell, Vermont and the installation or upgrade of approximately 16.9 miles of transmission line and associated substations in Lowell, Westfield and Jay, Vermont	)	Docket No. _____

PREFILED TESTIMONY OF

JOHN L. ZIMMERMAN

ON BEHALF OF GREEN MOUNTAIN POWER CORPORATION

May 21, 2010

Summary of Testimony

Mr. Zimmerman identifies the expected wind resource that will be available for electric generation. He also describes the extent of potential ice throw and shadow flicker and whether they will adversely affect public safety or aesthetics.

PREFILED TESTIMONY OF JOHN L. ZIMMERMAN
ON BEHALF OF
GREEN MOUNTAIN POWER CORPORATION

1. Q. Please state your name, current position, employer and business address.

A. My name is John L. Zimmerman. I am the owner and President of the wind power development consulting firm, Vermont Environmental Research Associates ("VERA"). VERA's business address is 1209 Harvey Farm Road, in Waterbury Center, Vermont 05677.

2. Q. Please state briefly your educational background and business experience.

A. I received my bachelor's degree in Environmental Administration from Johnson State College, and a Master in Business Administration from the University of Vermont. I am the owner of Vermont Environmental Research Associates, Inc. (VERA), a consulting firm that provides project management and analytical services to the regulated and non-regulated arms of the electric utility industry, with a focus on large-scale wind power plants. As the owner of the firm, I am responsible for all of its business endeavors including guiding its strategic direction. On a day to day basis, my primary areas of responsibility for our clients include project management work, business strategy development, performing financial and feasibility analyses, technical report preparation and overseeing the work of VERA's several technical staff members and consultants. Since the late 1980s much of VERA's work has been associated with the project development, financing, and permitting of commercial wind power facilities. For example, under my direction, VERA was responsible for the early wind resource assessment and siting work for Green Mountain Power Corporation's ("GMP's") establishment of the first utility-sponsored wind program in the country, which led to the development of both GMP's pioneering wind power facilities on Little Equinox Mountain (1989) and the Searsburg Wind Power Facility (1997). Since Searsburg, VERA has worked closely with several national wind development firms establishing and managing their northeast regional offices. In addition to being responsible for setting their strategic direction, VERA also provided specialized skills and technical capabilities that are needed in wind project development. VERA conducts wind site assessments, wind resource assessments, financial analyses, along with providing Geographic Information Systems (GIS) mapping services; wind turbine micrositing and wind facility design optimization; visual simulations of wind facilities; shadow flicker analyses and mapping; and estimations of the long-term energy production and economic performance of wind facilities. To support the analytical work, we use specialized software including ARC GIS 9.3, Windpro 2.5, WaSP 9, Windfarmer 4 and other data processing and analysis programs. We routinely work closely with civil and electrical engineers, environmental scientists, and legal professionals. Under my guidance, VERA also performed a number of assignments for the Vermont Department of Public Service ("DPS"), including a hypothetical estimation of wind power potential on Vermont's public lands (2003), the production of state-wide county wind resource maps (2004), the wind siting consensus-building workshops (2002), and initiation and management of the Vermont small wind turbine network program (2005-2009) monitoring performance, maintaining a program data website and assisting with maintenance of a eighteen turbine network of small wind turbines across the state of Vermont. All these reports are public information.

3. Q. Have you ever testified before the Public Service Board?

A. Yes. I provided testimony in Dockets 5823 (Searsburg Power Wind Facility); 7250 (Deerfield Wind); NM-297 (Teal Farm); and 7508 (Georgia Mountain Community Wind Project) along with several "248" filings for wind measurement tower installations.

4. Q. What is the purpose of your testimony?

A. My testimony will provide a wind resource assessment and the resulting energy production estimates for the Kingdom Community Wind ("KCW") Project, a shadow flicker analysis and an assessment of the issues presented by ice accumulating on the wind turbine rotor blades.

<u>Wind Resource Assessment</u>

5. Q. Can you describe the wind resource at the Lowell Mountain site on a qualitative basis and put it in perspective with other sites?

A. Yes. The U. S. Department of Energy wind power classification scheme, developed in the 1980s, is often used world-wide to describe the general quality of the wind resource by variations in wind speeds found at given heights above ground cover. Wind speeds (expressed as long-term annual mean wind speeds) are classified in 1 of 7 wind speed classes, with low wind speeds falling into lower numbered wind classes.

Wind Speed Class	Wind Speeds at 70 m. (229.6 ft.) above effective ground cover MPH (M/S)	Resource Potential
1	0 -12.8 (0 -5.8)	Poor
2	12.8 -14.9 (5.8 -6.7)	Marginal
3	14.9 -16.3 (6.7 -7.3)	Fair
4	16.3 -17.7 (7.3 -7.9)	Good
5	**17.7 -18.7 (7.9 -8.4)**	**Excellent**
6	18.7 -20.6 (8.4 – 9.2)	Outstanding
7	> 20.6 > 9.2	Superb

Table 1: Wind resource classification table developed by the US Department of Energy (DOE.NREL). Note: 230 ft (70 m) “above effective ground cover” corresponds to an approximate 262 ft (80 m) hub-height wind turbine, when ~33 ft (10 m) is assumed to be the effect height of the vegetation.

The estimated long-term wind speed at a height of 262 ft. (80 m) above- ground level for the KCW Project is within the Class 5 wind category of Table 1, representing an “Excellent” wind resource.

When searching for attractive wind sites in the interior New England region, wind power developers typically use a hub-height wind speed of 15.6 mph (7.0 m/s), which is just below the Class 4 range, as a threshold value for identifying sites with an adequate wind resource.

6. Q. Please generally describe the wind measurement program conducted for KCW.

A. The collection of on-site wind data at the KCW Project involves two separate wind measurement programs. A previous developer undertook the first measurement program from June 2003 to May 2008 and the second involves the new meteorological towers. We will supplement the data collected in the first measurement program with data from this second measurement program, which we will use to micro-site KCW wind turbines and thereby increase Project performance. **Exh. Pet.-JLZ-1** identifies the locations of the meteorological stations used in both wind measurement programs.

The 2003-2008 measurement programs involved two meteorological stations ("Met Stations" or "Stations") sited approximately 2.5 miles (4.0 km) apart on the Lowell Mountain range at locations considered to be representative of high and low elevations along the ridgeline. The Met Stations consisted of 164 ft. (50 m) high towers with redundant anemometers and wind direction vanes installed on 4.3 ft. (1.3 m) standoff booms installed at heights of 98 ft. (30 m), 131 ft (40 m), and 164 ft. (50 m) above ground level. Table 2 sets forth further information relating to the sites.

	Met Station 808	**Met Station 809**
Elevation	2570 ft (783 m)	2210 ft (674 m)
Period of Operation	18 June 2003- 14 May 2008	18 June 2003- 28 July 2007
Nominal tree canopy height	25 ft (7.5 m)	37 ft (11.25 m)
Latitude (N)	44.74836	44.77689
Longitude (W)[1]	72.42536	72.39252

Table 2: Met Stations 808 and 809 locations and site information.

[1] Geographic datum for latitude and longitude is WGS 84.

VERA subjected the data collected from the wind measurement stations to a quality assurance process by screening and filtering for consistency, accuracy and sensor failure. For the period June 18, 2003 through May 14, 2008, data recovery for both Met Stations was 89.1%, corresponding to 38,315 hours of coincident data used in further analyses. The original Met Stations were removed in the spring of 2008.

The second measurement program, involves three Met Stations sited along an approximate 3 mi. (4.0 km) section along the Lowell Mountain range. The Met Stations consist of two 262 ft. (80 m) high towers (A and C) and one 164 ft. (50 m) high tower (B), each with several levels of meteorological sensors. The 50 meter station is located in the same location as Met Station 808, to provide data correlation continuity back to the earlier program.

7. Q. Please summarize the results of the first measurement program.

A. Wind speed summary statistics are shown in Table 3. The measured average wind speed at 164 ft. (50 m) was 16.5 mph (7.4 m/s) at station 808.[2]

Parameter	Met Station 808
50 m Measured Average Wind Speed	7.4 m/s (16.5 mph)
30 m Measured Wind Speed (mph)	7.0 m/s (15.4 mph)
50 m Weibull Probability Dist. Parameters	18.05/2.36
Prevailing Wind Direction	NW

Table 3: Observed wind statistics at the two Met Stations.

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[2] The information from Station 809 is not included because the station was located outside the KCW Project boundary area.

The directional distribution of the energy in the winds is illustrated for each of 12 direction sectors in Figure 1.

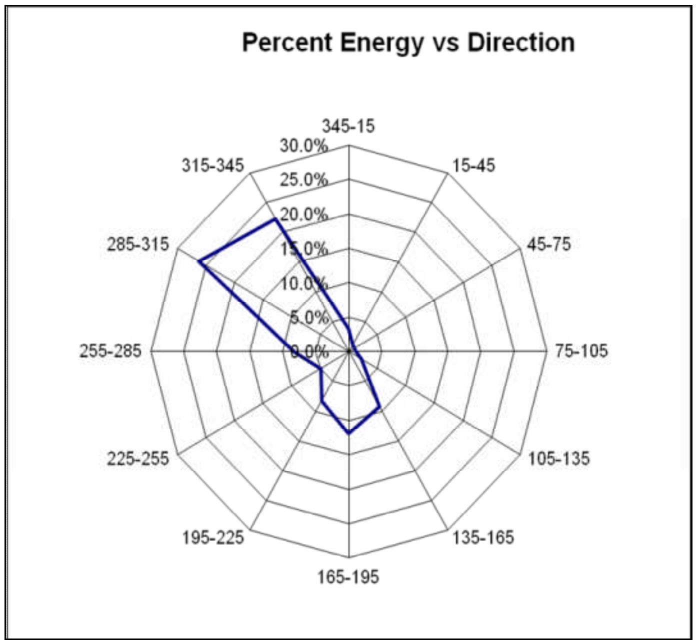

Figure 1: Average annual wind energy directional distribution of the 50 m winds at station 808.

Turbulence intensity (TI), or the short-term variability of wind speeds, is an important consideration in the siting of wind turbines because it increases the mechanical loads on wind turbines. It is a parameter used in defining wind characteristics in IEC standards[3], and in determining whether a particular wind turbine is suitable for installation at a particular site. The mean TI at 33.0 mph (15 m/s) is used in characterizing turbulence in terms of the IEC standards. The mean turbulence intensity at station 808 was 11.3% based on 2,698 ten minute periods of

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[3] International Electrotechnical Commission (IEC) Standard 61400-1, ‘Wind Turbine-Part 1: Design requirements’, Third Edition, 2005-08.

data.[4] This is considered low turbulence according to the IEC standards.

8. Q. How does this data compare to long-term wind data?

A. Although NOAA National Weather Service information for the nearest airports with weather data (Burlington and Morrisville) was not sufficiently similar to the data produced by station 808 to be helpful in estimating longer-term values, information from Burke Mountain 3260 ft (994 m) in elevation and approximately 30 miles to the southeast of the Lowell Mountain range was sufficiently similar in terms of local climatology. VERA used the Burke Mountain wind data, collected with heated anemometers, as the long-term reference from which we derived long-term wind speed estimates for Lowell. We made no adjustments to the measured data, because the measured values over coincident measurement periods at Lowell were within 1.5% of the long-term values at Burke over the 1999 – 2005 measurement period. We therefore considered these measurements to be representative of long-term annual mean wind speeds. Because data recovery rates are lower in the winter months (due to ice accumulating on the wind sensors) when wind speeds are higher, annual average wind speeds were then calculated as the mean of the monthly mean wind speeds to remove this source of seasonal bias. The resulting long-term annual mean wind speed at Lowell station 808 is 17.3 mph (7.8 m/s) at 164 ft. (50m) above ground level.

VERA then calculated the wind shear (the difference in wind speeds) between the 30m and 50 m sensor heights and extrapolated to the nominal 262 ft. (80 m) hub height of wind turbines using

[4] Turbulence Intensity is calculated as the standard deviation of wind speed samples taken at 3 second intervals divided by the mean of these samples over a 10-minute period.

standard wind industry methods. The resulting estimates for the long-term annual mean wind speeds at hub-height were calculated to be 18.3 mph (8.2 m/s).

9. Q. Please summarize the method used to site the wind turbines along the Lowell Mountain range and estimate the long-term energy production for a facility typical of what is being contemplated for the KCW Project.

A. VERA developed an estimate of the net annual energy production for the KCW project by simulating the output of the turbines that may be used, based on the above wind data, the air density-corrected power curves for the wind turbines under consideration. VERA used WAsP modeling software to model the wind flows over the ridgeline and to calculate a matrix of hub-height wind resource statistics that take into account the wind speed and directional distributions at the wind measurement location along with broader scale topographic and surface roughness considerations.[5]

VERA input the resulting WAsP output into an energy production simulation program (WindFarmer) that "micro-sited" the wind turbines along the ridge to maximize energy production. The program calculates energy production for each wind turbine and the most efficient turbine spacing, taking into account expected losses from availability, turbine wakes, electrical losses, icing and other factors. It also considered siting constraints that include property boundaries, buffers around sensitive environmental areas, distance between turbines,

[5] It has been noted that in complex terrain, WAsP has overestimated energy production in some cases. "Uncertainties when Production-estimating with WAsP." Ole Rathman and Niels G. Mortensen. 1/14/2009. http://windpower.customers.composite.net/media(2745,1030)/Presentation_5.pdf. Based on an analysis of the potential for this effect, a complex terrain adjustment is unnecessary for the KCW Project.

and ground slopes parameters. Based on the analyses to date, it appears that GMP could site up to 21 wind turbines within the Project area, using wind turbines with 262 – 328 ft. (80 -100 m) rotor diameters and a turbine to turbine minimum spacing of 2.5-3.0 rotor diameters. Depending on the wind turbine selected for this project, this represents a range of estimated annual net energy production for a KCW Project between approximately 150,000 to 160,000 megawatt-hours. VERA will refine these estimates once new information from the GMP wind measurement program is available. At the request of GMP, VERA performed an energy analysis for 21 VESTAS 3.0 MW V90 turbines (80 meter hub height with 90 meter rotor diameter). The analysis indicated that the expected annual output for the 21 VESTAS units, when adjusted for electrical losses to arrive at the delivery point of the VELCO Jay Tap Substation, to be approximately 149,000 MWH. Further analysis of the expected energy production will be performed upon selection of the final turbine and when new wind measurement data becomes available.

<u>Shadow Flicker</u>

10. Q. Can you describe shadow flicker and why it should be evaluated?

A. Shadow flicker relates to the shadows created by a wind turbine's rotor and has been described as follows:

> "As the blades of a wind turbine rotate in sunny conditions, they cast moving shadows on the ground resulting in alternating changes in light intensity. This phenomenon is termed shadow flicker. Shadow flicker is different from a related strobe-like phenomenon that is caused by intermittent chopping of the sunlight behind the rotating blades. Shadow flicker intensity is defined as the difference or variation in brightness at a given location in the

> presence and absence of a shadow. Shadow flicker can be a nuisance to nearby humans, and its effects need to be considered during the design of a wind-energy project. In the United States, shadow flicker has not been identified as causing even a mild annoyance. In Northern Europe, on the other hand, because of the higher latitude and the lower angle of the sun, especially in winter, shadow flicker can be a problem of concern." [6]

The extent to which shadow flicker is a nuisance depends on several factors, including the relative locations of the sun, the wind turbine, and the observation point, the wind speed and direction, the daily variation in sunlight, local topography and ground cover that may present obstructions, and the geographic latitude of the location. Flicker frequency depends on the rotation frequency of a turbine's typically 3-bladed rotor (i.e., 0.6-1.0 Hz). Shadow flicker is not a problem during overcast days, when the direct sunlight is blocked by clouds or fog, or when there are visual obstructions between the wind turbines and the viewer, such as topography, buildings and vegetation. Shadow flicker lasts no more than a short time each day, rarely more than a half an hour – coinciding with a specific daily location of the sun, as it moves across the sky. The intensity and frequency of shadow flicker declines as the observer's distance from the wind turbine increases.

There are no standards establishing acceptable levels of shadow flicker or the appropriate assumptions for modeling flicker. The general industry practice, however, is to model shadow flicker to a distance of at least 3,280 ft. (1,000 m) from the wind turbines.

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[6] Committee on Environmental Impacts of Wind Energy Projects, National Research Council, "Environmental Impacts of Wind-Energy Projects", National Academies Press, 2007 (emphasis added). p. 160.

VERA modeled shadow flicker at the KCW Project using WindPro (version 2.5) software. WindPro calculates the position of the sun relative to the wind turbines for each minute of the year to determine where, when, and for how long a wind turbine's shadows will be cast on the surrounding landscape.

We performed two analyses for the KCW Project using a "worst case" and an "expected case" set of assumptions. Both analyses assumed that a 21 turbine configuration would be constructed and that the shadow intensity does not diminish with distance. Other inputs into the model for the worse case analysis include:

Input Data	Data Source
Wind turbine locations	Entered as geographic coordinates (21 Turbine Layout)
Wind turbine rotor diameter	328 ft. (100 m); GE 2.5 xl
Wind turbine hub-height	279 ft. (85 m); GE 2.5 xl
Digital elevation and base map data	NED 1 Arc Second DEM and 1:24000 USGS Topographic maps

Table 4: Data sources for the modeling of the worst-case shadow flicker analysis at KCW.

Our worst-case scenario assumes the absence of clouds or other atmospheric obstruction during daylight hours, turbine operation during all hours of the year, rotor orientation that maximizes shadow impact on the observer, and the absence of ground level visual obstructions due to topography, vegetation or structures. VERA's expected case scenario, on the other hand, reflects cloud cover, turbine operation, and rotor orientation data based on historical records, and actual ground level visual obstructions. It therefore produces more representative results.

Input Data	Data Source
Ground cover data	NLCD 2001 data layer available from the VCGIS database
Weather data (cloud cover)	Morrisville, VT NOAA ASOS station
Operating Data from the joint wind speed and direction frequency distribution data	Data from measurement station 808, collected over the period June 2003 – May 2008

Table 5: Additional data inputs and source used to model the expected case shadow flicker results.

I have presented the results of two analyses on the maps that display contour lines representing the total number of hours per year shadow flicker can be expected up to 6,560 ft. (2,000 m) away from the wind turbines. The two maps are included as **Exh. Pet-JLZ-2**.

Under worst-case assumptions, we expect fewer than 40 hours per year of shadow flicker at the distances of the nearest residences (3,280 ft. (1,000 m)). Under the expected case assumptions, the number decreases to ten hours per year and the amount of area affected decreases because we take into account ground cover (e.g., forested areas). In both analyses, shadow flicker is generally limited to morning and/or evening periods of short duration (less than 30 minutes) of up to several weeks. This amount of shadow flicker is consistent with that amount we identified for the Deerfield and Georgia Mountain wind turbine projects based on similar techniques and assumptions.

<u>Icing</u>

11. Q. Will you discuss the phenomenon of "icing" and risks to humans associated with ice falling from the KCW Project wind turbines?

A. Icing is caused by (1) freezing precipitation that glazes exposed surfaces, including wind turbine rotors, or (2) rime ice accretions caused by super cooled water droplets in clouds or fog that freeze upon contact with a surface that is below the freezing point. Under certain conditions, a rotor may release the built-up ice ("ice throw"), which can cause injury to persons sufficiently close to the wind turbine. The risk to humans of being injured by ice falling or thrown from a wind turbine rotor decreases with distance from the wind turbine. The frequency and distance of ice throw from large wind turbines was the subject of several European studies in the late 1990s and early 2000s, including a widely-referenced study by Henry Seifert et al.[7], that identified an area of risk ("Seifert risk circle")[8] for ice throw. More recent <u>empirical</u> studies by Rene Cattin and others[9] and sponsored by the Swiss government, documented over a two winter period the size, weight and horizontal distance of ice fragments falling from an operating wind turbine in heavy icing conditions. The furthest fragment found from the turbine base was 301.7 ft (92 m). A 2005 <u>theoretical</u> study conducted by Garrard Hassan of the risks from ice falling from 328 foot high (100 m) proposed wind turbines on East Mountain in East Haven, Vermont[10] (the "EHWF" project) found the risks to humans to be low. An important conclusion of this study, in terms of risks to humans near a wind project is:

> " . . . based on our previous work and accounting for the terrain and machine size of the EHWF site, a very conservative estimate

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7 *Risk* Analysis *of Ice Throw From Wind Turbines,* Seifert et al., (2003).

8 The Seifert risk circle is expressed in terms of the height of the structure alone as: (1.5 times the sum of the rotor diameter plus the hub-height). This formula was based on wind turbines are smaller than those used today. It has been criticized as overstating the risk of larger turbines, because it assumes that maximum rotor tip speed increases in direct proportion to turbine blade size, whereas maximum rotor tip speed (68 – 80 m/s or 150 – 180 mph) is in fact relatively constant, because larger rotors rotate more slowly and therefore blade speed through the air is approximately the same.

9 Wind Turbine Ice Throw Studies in the Swiss Alps, Cattin, Rene, et al., (2008 assumed).

10 Assessment *of Ice Throw for the Proposed East Haven Wind Farm*, LeBlanc, M.P. for Garrad Hassan, February 2005.

> for the maximum achievable distance for ice to be thrown is considered to be 400 m (1315 ft), assuming an area within the maximum achievable distance from the proposed EHWF turbines is populated by one ever-present person during all icing conditions and that person is equally likely to be in any given 1 m^2 within that area, it is possible to estimate the risk for one person from ice throw. This risk assuming no one impinges within 40 m (130 ft) of a turbine base, and assuming that no control method is employed to prevent ice throw is 1 in 11,000,000."

This risk is less than seven percent of the 1 in 750,000 risk of an individual being struck by lightning. The Cattin and Garrard Hassan studies are included as **Exh. Pet.-JLZ-3**, and **Exh. Pet.-JLZ-4**.

The ice impact risk to the public associated with the KCW Project is extremely low, based on the results of the above studies and because there are no public roads or trails within the distance ice could be thrown from Project turbines and there is no public accessibility to the Project access roads.

Furthermore, signage will be posted around the wind turbines to alert hikers or hunters who may have obtained access through other means and are present in close proximity to the wind turbines, to the potential danger from ice during winter operating conditions. Maintenance personnel will also be trained to follow industry standard safety procedures when working in close proximity to wind turbines when icing conditions are present.

12. Q. Does this complete your testimony?

A. Yes.